Research Bulletin No. 2 July 1913

Oregon Agricultural College
Experiment Station

AN

Investigation
OF
Lime-Sulfur Injury
ITS
Causes and Prevention

By
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Corvallis, Oregon

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GENERAL CONSIDERATIONS.

The term "lime-sulfur injury" has been understood generally to include all forms of injury to fruit or foliage following an application of lime-sulfur and apparently induced by such application. The term, unfortunately, does not imply that the injury was caused directly by chemicals occurring in the spray mixture. This indefinite use is due to the lack of definite knowledge of the causes of what has been loosely called "spray injury." If but one factor were concerned in the occurrence of lime-sulfur injury, the problem would be comparatively simple, and the apparently inconsistent results that have been obtained would perhaps not persist.

The first explanation that occurs to a grower who notices leaf or fruit injury shortly after an application of lime-sulfur, is that of an insufficient dilution. In other words the spray was "too strong." The explanation would be very simple were it not for the fact that in several instances, under similar conditions, a "weaker" spray has apparently caused injury where a "stronger" spray proved harmless. Results of this character indicate that the strength of the spray is not the primary cause of the injury. Lime-sulfur injury is a complex problem requiring a different explanation for each of its various causes.

At the present writing * Wallace, of Cornell, is the only investigator who has suggested an explanation, based upon scientific observations, for some of the apparent inconsistencies encountered in the occurrence of lime-sulfur injury. The work herein reported concerns the chemically injurious ingredients of the lime-sulfur spray and a class of injuries that are due to other causes than the character or strength of the spray.

In an investigation of this nature it should be emphasized that in citing the results of others only the works of scientifically trained men should be taken into consideration unless cooperative experiments are carried on by growers under the direct personal supervision of an expert. Personal supervision does not mean merely an outline of directions for the growers to follow, but the presence on the ground of a specialist who will see that the directions are accurately followed and the results accurately observed. The New York State (Geneva) Experiment Station, in sending out inquiries into the cause of "spray injury," received answers so varied that some of them would perhaps stumble upon a true solution. Herewith are quoted some of the answers received:

"Rapid growth of fruit and foliage."
"Leaves young and tender."
"Too much rain."
"Cold weather and rain."
"Cloudy conditions."
"Lack of sunshine."
"Prolonged cloudy weather."
"Sunshine following showers."
"Excessive use of spraying mixtures."
"Spraying while dew is on the foliage."

The fallacies in such work are frequently due to lack of proper check experiments, or the drawing of but one conclusion to cover several phases of the problem. What, moreover, shall we say of the human failing to exaggerate and jump at conclusions? We know of instances where growers have seen a few spotted leaves and immediately pro-

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Manuscript submitted for publication at the close of 1911.

claimed the occurence of spray injury, though subsequent examinations failed to show the presence of any other injured leaves in the whole orchard. In the records even of scientific workers, "russet," when occurring in plots sprayed with lime-sulfur, has quite universally been attributed to the spray. The work of Bonns, a few others, and our own results have shown that "russet" may occur independently of the character or strength of the spray.

These remarks merely suggest that much of the "lime-sulfur injury" is in reality due to other causes.

THE INJURIOUS INGREDIENTS IN LIME-SULFUR.

In the early part of December, 1910, a series of experiments were outlined to ascertain the chemicals occurring in the lime-sulfur spray that were injurious to foliage. This was the primary problem regardless of other questions presenting themselves from time to time. It had been suggested by Volck and later by Wallace that the soluble sulfides were the injurious compounds. No experiments had been conducted on this point, however, and definite data on the injury caused by the soluble sulfides have been lacking.

In the experiments, the materials with which the spray was made and the compounds occuring or liable to occur in the spray before or after application, were used. When a particular compound could not be separated, the group in which it occurred was used; as for instance, calcium polysulfides, consisting of CaS_5, CaS_4, with traces of CaS_2O_3. Almost all the chemicals used in the experiments with the exception of the modified lime-sulfur mixtures were prepared by Professor H. V. Tartar, chemist of the Oregon Experiment Station, with whom the author conferred frequently and to whom he is indebted for many favors.

Experiments on Potato Foliage.

For the first series of experiments, potato plants, grown in a cool greenhouse, were used. The plants grew very rapidly, causing the foliage to become larger and more tender than would occur in the field. The plants were free from diseases but slightly attacked by the white fly. One to several plants, averaging together about twenty leaves, were sprayed with each of the materials used. The results clearly indicated the compounds that are liable to be injurious. This character of injury; namely, injury caused directly by chemicals in the spray, is due to the strength of the soluble sulfides used. The prevention of such injuries is accomplished by (1) increasing the dilution, (2) rendering the injurious compounds insoluble. These points will be discussed later.

The most chemically active compounds found in lime-sulfur are the calcium polysulfides. These are, primarily, CaS_4 and CaS_5, which together with perhaps some lower sulfides give to the concentrated spray the red color. The polysulfides are very strong reducing agents and to this property, we think, is due the injury caused to foliage by the polysulfides break down to the calcium thiosulfate (CaS_2O_3), which is colorless. The depth of color of the lime-sulfur, then, increases with the polysulfides in solution. Both the calcium polysulfides and the calcium thiosulfate are soluble in water. These are the chemicals these compounds. Upon exposure to air or other decomposing agencies, according to our experiments, that may cause injury to foliage. The further products of the decomposition; namely, $CaSO_3$, $CaSO_4$ and free sulfur, are practically insoluble and non-injurious.

When injury occurred, except in serious cases where the whole leaf

was scorched, it was generally at the tip, the "scorch" extending toward the centre of the leaf in proportion to the severity of the injury. Frequently the leaves curled slightly before showing the injury. The materials in solution or suspension were applied with an atomizer, to both upper and lower surfaces.

In clear, concentrated lime-sulfur preparations, the amount of polysulfides is very variable. An approximate average would be about 35%. A 1% solution, approximately equivalent to a 1 to 35 dilution, probably stronger, sprayed upon potato foliage, was not injurious except in one experiment where the plant was drenched heavily with the polysulfides. In this case, 18 leaves were sprayed, of which number the edge of the tip of two oldest leaves showed slight burn. In the table the calcium polyslfides are termed ($CaS_4 + CaS_5$).

In each experiment recorded here, one half-grown leaf was severely pricked on both its upper and lower surfaces immediately before spraying. This was to obtain an indication of the bearing of such a condition upon spray injury. In the applications of 1% calcium polysulfides the pricked leaf healed without any signs of spray burn.

A 5% solution of calcium polysulfides injured the foliage in all the experiments. Rain water, applied as a spray five minutes before the application, did not decrease the injury. On the other hand, a spray of rain water applied five hours after the application apparently reduced the injury. This would indicate, contrary to the popular opinion, that injury due to the soluble sulfides is decreased by rain following shortly after the application; it would indicate also that the polysulfides, though dry, may still cause injury, as evidenced by the additional injury caused by the dry polysufide that was not rain-sprayed. Shafer of Michigan has shown that the dry lime-sulfur as well as the liquid absorbs oxygen. This fact tends to strengthen our belief that the injury caused by the polysulfides is directly due to their strong powers of reduction.

In all cases of spray injury encountered in the experiments on potato foliage, the oldest leaves were the most severely, and frequently the only leaves, injured; the youngest were next in order, while the half-grown leaves were most resistant. These results are suggestive as an explanation of the reason that later applications have proved most injurious. This explanation would admit that of Wallace (who accounts for this action on the basis that the older leaves had a greater fungus infection) as a contributory cause.

Tartar thinks it probable that CaS_2 is the most stable compound of the polysufides. A .5% solution of CaS_2 (containing traces of CaS_2O_3) in an even spray applied to twenty-five leaves injured but slightly the tips of two old leaves. The pricked leaf healed without showing any signs of spray injury. In drenching a plant with this strength the injury was not appreciably more severe. Of 15 leaves sprayed, the edges of two old leaves were slightly burned. The pricked leaf healed without showing any spray injury.

An interesting comparison may now be made that is very suggestive. It was noticed, as recorded above, that a 1% calcium polysulfide, composed for the most part of CaS_4 and CaS_3, caused no injury except when used as a drenching spray, in which case the injury was slight. On the other hand, a solution of a lower calcium polysulfide of but half the strength, caused injury. This would indicate that the lower polysulfides are the most injurious, and perhaps the most actively insecticidal compounds in the spray. A tentative explanation of the reason for this may be that though a certain amount of the higher polysulfides, say CaS_5, takes up as much oxygen as the same amount of CaS_2, still in a solution containing a certain quantity of sulfur in the form of polysulfides, the greater amount that is in the form of CaS_2, the greater

will be the absorption of oxygen. This again agrees with our suggestion that the reduction powers of the polysulfides cause leaf injury. In this case a .5% solution of CaS_2 was a greater reducing agent than a 1% solution of the higher polysulfides.

The problem of the separation of the various polysulfides possesses great possibilities. This problem, purely chemical, is at the present time being investigated by Professor Tartar.

Calcium thiosulfate, in concentrated lime-sulfur, occurs in much more variable quantities than do the polysulfides. A solution of .1% and .5% caused no injury either as a fine spray or a drenching spray. To ascertain whether a much stronger thiosulfate, (one equivalent to most of the decomposed polysulfides) would be injurious, plants were sprayed with a 4% solution. Of 18 leaves sprayed with an even application, only the pricked leaf and the tip of one old leaf showed slight injury. When the plant was drenched, the injury was more severe, including several young leaves. A plant having 25 leaves sprayed evenly with this strength and kept in a warm room showed injury on the pricked leaf, the tips of two old leaves and the tips of two young leaves. The half grown leaves were not injured by any of the thiosulfate applications.

Calcium monosulfide (CaS) does not occur in lime-sulfur. Its action on the plant, however, in slowly liberating H_2S is similar to the action of the lime-sulfur spray in contact with the CO_2 of the air. To test the possible effect of this chemical activity on the foliage, a strength of .1% CaS and .5% CaS were used. To obtain an indication of the or the drenching spray. To obtain an indication of the possibility of possibility of injury from this source, a saturated solution of H_2S was used. The plants were heavily sprayed and covered with bell jars. No injury occurred.

Several commercial brands of lime-sulfur were tested. The concentrated spray, applied evenly, severely burned all the leaves. At a dilution of 1 to 10, the injury was less, though still severe, being greater with an increased density. The brands used tested 29.6° B., 31.6° B. and 35° B. The latter strength, diluted 1 to 25, caused practically no injury, only the tip of one old leaf showing signs of burns. The pricked leaf showed no injury.

Tartar and Bradley have shown that calcium ıydrosulfide ($Ca(SH)_2$) does not occur in lime-sulfur. Other chemists had previously claimed $Ca(SH)_2$ to be present in the spray. To test the possible effect of this compound, a .5% preparation of $Ca(SH)_2$ was applied, both evenly and as a drenching spray, upon potato foliage; no injury resulted.

As has been stated, the polysulfides break down to the thiosulfate. This latter decomposes slowly to form the sulfite of calcium, which in turn takes the form of calcium sulfate. The latter two products which are almost insoluble are not injurious to foliage. Neither is free sulfur nor calcium hydroxide. A heavy application of lime paste to the leaves of the potato, caused them to wilt, due to the weight imposed upon the leaves, to the stopping of the stomates, and the exclusion of sunlight. A less heavy dressing of the same material was not injurious.

The results obtained from the pricked leaves are not conclusive. In experiments 34 and 35 (see Table), in which one plant received an even spray and the other a drenching spray of .5% CaS_2, the pricked leaves showed no signs of spray injury while older unpricked leaves showed slight injury. In experiment 39, a drenching spray of 1% calcium polysulfide injured several old leaves slightly without apparently injuring the pricked leaf. On the other hand, in experiment 42 a 5% calcium polysulfide, followed in five hours by a light rain, badly burned the pricked leaf but only slightly burned several old unpricked

leaves. In experiment 55 a commercial brand testing 35° B., diluted 1 to 25, injured the top of a large leaf without apparently injuring the pricked leaf.

According to these results, rain immediately preceding the application seems to have no appreciable effect, while a rain following an application that might prove injurious otherwise, tends to decrease or prevent the injury by (1) washing off some of the soluble sulfides, which are the injurious compounds, (2) diluting the sulfides on the leaf, and (3) hastening their decomposition.

No further data were sought or obtained, in this set of experiments, upon the possible effect of weather conditions on spray injury, except in the case of experiment 56, where the plant was kept in a warm room, frequently receiving the direct rays of the sun. In this case, the plant was more severely injured than similarly treated plants in the cool greenhouse. The greenhouse plants were seldom exposed to the direct rays of the sun.

What data were obtained on the effect of a drenching spray compared to an even spray, point to the fact that has already been observed, namely, that a drenching spray increases the injury or is liable to cause injury where an even spray is harmless. This is not peculiar to the lime-sulfur spray. It is well known that many solutions are injurious in large drops and harmless in much smaller drops. As far as lime-sulfur is concerned, another element enters here. The smaller the drop, the larger in proportion is the surface exposed to the air and the more rapid the decomposition. **The drop of spray is generally stronger when it first touches the leaf than at any stage between that and complete evaporation.** The conditions that tend toward evaporation tend also to decomposition and to the removal of the injurious compounds. The statement found in the literature that, "The amount of spray injury was found not to depend exactly upon density of application but rather upon the density attained on the leaf before evaporation is complete," seems to have no significance whatever. **For if the solution on the leaf decomposes, then the decomposition removes the injurious compounds.. If it does not, then the solution goes through all the stages of concentration until complete evaporation takes place.** In the case of only partial decomposition the same holds true; for, as long as any of the solution dries without undergoing chemical change, it must have passed through all the stages of concentration.

The following table gives the results of the potato foliage experiments:

Table I.

EFFECT OF LIME-SULFUR INGREDIENTS UPON POTATO FOLIAGE

Expt. No.	Materials Used	Remarks	Effect	Further Remarks
1	.01% $CaSO_3$	Suspended in water	No injury	
2	.01% $CaSO_3$	Rain spray before and after	No injury	
3	.01% $CaSO_3$	Rain spray before application	No injury	
4	.05% $CaSO_3$	Suspended in water	No injury	
5	.05% $CaSO_3$	Rain spray before and after	No injury	
6	.05% $CaSO_3$	Rain spray before application	No injury	
7	.01% $CaSO_3$	Plant drenched	No injury	
8	.05% $CaSO_3$	Plant drenched	No injury	

13	.01% $CaSO_4$	Suspended in water	No injury	
14	.01% $CaSO_4$	Rain spray before and after	No injury	
15	.01% $CaSO_4$	Rain spray before application	No injury	
16	.01% $CaSO_4$	Plant drenched	No injury	
17	.05% $CaSO_4$	Suspended in water	No injury	
18	.05% $CaSO_4$	Rain spray after application	No injury	
19	.05% $CaSO_4$	Rain spray before application	No injury	
20	.05% $CaSO_4$	Plant drenched	No injury	
21	Flour sulfur (sifted on)	Rain spray before application	No injury	Large leaves heavily sprinkled began to wilt but recovered
22	Filtered lime water		No injury	
23	Lime paste (1-2)	Plant drenched	Leaves, covered thickly, began to wilt next day. No signs of burning effects. See No. 50.	
50	Lime paste	Light covering on leaves	No injury	
9	.1% CaS^2O_3	Solution	No injury	
10	.1% CaS_2O_3	Rain spray before and after	No injury	
11	.1% CaS_2O_3	Rain spray before application	No injury	
12	.1% CaS_2O_3	Plant drenched	No injury	
24	.5% CaS_2O_3		No injury	
25	.5% CaS_2O_3	Rain spray before application	No injury	
26	.5% CaS_2O_3	Rain spray after application	No injury	
27	.5% CaS_2O_3	Plant drenched	No injury	Three large leaves slightly curled.
51	4% CaS_2O_3		Pricked leaf slightly burned also tip of one large leaf. (Sprayed 14 leaves)	
52	4% CaS_2O_3	Plant drenched	Pricked leaf, one large leaf and several small leaves slightly burned. (Sprayed 10 leaves)	
56	4% CaS_2O_3	Kept in warm room	Pricked leaf two large leaves and two small leaves show burn at tip (Sprayed 25 leaves)	
28	.1% CaS		No injury	
29	.1% CaS	Plant drenched	No injury	
30	.5% CaS		No injury	
31	.5% CaS	Plant drenched	No injury	
32	Sat. Sol. H_2S	Covered with bell jar three days	No injury	
33	Sat. Sol H_2S	Plant drenched and covered	No injury	

34	.5% (CaS_2+ some CaS_2O_3)	Rain spray before preceding rain	Tip of two large leaves slightly burned	Pricked leaf well healed. (Sprayed 25 leaves)
35	.5% CaS_2+ some CaS_2O_3)	Plant drenched	Edges of two large leaves slightly burned	Pricked leaf well healed. (Sprayed 15 leaves)
36	1% CaS_4+ CaS_5)	1.007 Sp. Gr.	No injury	
37	1% (CaS_4+ CaS_5)	Rain spray after application	No injury	
38	1% (CaS_4+ CaS_5)	Rain spray before application	No injury	
39	1% (CaS_4+ CaS_5)	Plant drenched	Tip edge of 2 oldest leaves burned	Pricked leaf well healed. (Sprayed 18 leaves)
40	5% (CaS_4+ CaS_5)	1.035 Sp. Gr.	Young leaves severely burned. Half-grown slightly burned. Pricked leaf and large leaves burned	
41	5% (CaS_4+ CaS_5)	Rain spray before application	Pricked and small leaves most severely burned. Large leaves next and half-grown least. Injury apparently not lessened by preceding rain	
42	5% (CaS_4+ CaS_5)	Rain spray 5 hours after application	Pricked leaf badly burned, large leaves slightly burned, otherwise no injury. Injury lessened by rain following	
43	5% (CaS_4+ CaS_5)	Plant drenched	All leaves badly burned. Half-grown least injured of all	
44	.5% $Ca(SH)_2$		No injury	
45	.5% $Ca(SH)_2$	Plant drenched	No injury	
46	Lime-sulfur 29.6° B.	Concentrate	All leaves badly burned	
47	Lime-Sulfur 31.6° B.	Concentrate	All leaves badly burned	
48	Lime-Sulfur 1-10	No. 47 diluted	Old leaves severely burned. Young leaves slightly burned. Half-grown leaves least affected	
49	Lime-Sulfur 1-10	No. 46 diluted	Half-grown leaves not injured. Younger and older leaves slightly burned at tip	
53	Lime-Sulfur 35° B.	Concentrate	All leaves badly burned	
54	Lime-Sulfur 1-10	No. 53 diluted	Pricked leaf, old and young leaves burned. Half-grown least affected	
55	Lime-Sulfur 1-25	No. 53 diluted	Practically no injury	Pricked leaf well healed. Tip of one large leaf apparently burned

Experiments on Bean Foliage.

In order to verify results obtained in the potato foliage experiments, and to get additional data on the injury occurring on the leaves of a more tender plant, a similar series of experiments was performed upon beans, planted in the same greenhouse. The plants frequently

received the direct rays of the sun and an average of ten degrees more heat than the potatoes.

In these experiments a coarse spray was applied. The plants, when sprayed, averaged about seven leaves each. They were not in the best condition, due to excessive watering shortly after planting and to the infestation of the roots by several underground pests.

The results verify the conclusions drawn from the potato foliage experiments in locating the injurious ingredients. On account of the greater tenderness of the bean plant, weaker solutions of the polysulfides and the calcium thiosulfate caused more injury than on the potato foliage.

No conclusions could be drawn from the difference in degree of injury upon leaves at different ages. Occasionally the old leaves seemed to be least injured, due, perhaps, to the fact that more even diffusion of the spray on the leaf surface caused more rapid decomposition of the polysulfides. The surface of the young and middle-aged leaves did not allow the even spreading of the spray, which, collecting in large drops, caused more injury.

No definite results were obtained from the experiments on the pricked leaves of the bean. The injuries were generally so severe that a comparison of the degree of severity was difficult.

As in the experiments upon potato foliage, the insoluble, or but slightly soluble, compounds were non-injurious. Calcium sulfite, calcium sulfate, sulfur, and lime caused no injury, even in heavy applications. A saturated solution of hydrogen sulfide was likewise non-injurious. Calcium polysulfides at 1% and 3% injured all the leaves sprayed. Calcium thiosulfate was not injurious at a strength of .1% but injurious in .5% and 1% solutions. In the potato experiments, a suggestion was made to account for the injurious action of calcium polysulfides. Calcium thiosulfate, in decomposing, releases an atom of sulfur forming calcium sulfite and free sulfur. Whether the injury is caused by the nascent sulfur or by the formation of other compounds due to plant acids, we do not know at present.

Table II.

EFFECT OF LIME-SULFUR INGREDIENTS UPON BEAN FOLIAGE.

Expt. No.	Material Used	Remarks	Effect	Further Remarks
1	1% $CaSO_3$		No injury	
8	5% $CaSO_3$		No injury	
2	1% $CaSO_4$		No injury	
9	5% $CaSO_4$	Plant drenched	No injury	
3	Milk of Lime (5%+)	Plant drenched	No injury	Half grown leaves started to curl slightly in 5 days Pricked leaf healed
4	Sat. Sol. H_2S	Plant drenched	No injury	Kept plant under bell jar 3 days
5	Flour Sulfur	Heavy application on wet plant	No injury	
6	Flour Sulfur	Medium application on wet plant	No injury	
7	Concentrated Lime-Sulfur 29.6° B.	Medium application on wet plant, followed immediately by light spray	All leaves injured	Pricked leaf shows distinct scorch where pricked

10	1% (CaS_4+ CaS_5)	All leaves injured	Leaves badly curled
11	3% (CaS_4+ CaS_5)	Pricked and half-grown leaves badly scorched	Injury apparently not worse than in No. 10. Old leaves apparently uninjured
12	1% CaS_2O_3	All leaves injured	
13	.5% CaS_2O_3	All leaves injured	Injury less than in No. 12
14	.1% CaS_2O_3	No injury	

Experiments On Foliage and Fruit of Fruit Trees.

The final steps in this series of experiments were carried on in the College orchard during the latter part of the summer of 1911. The foliage and fruit of various fruit trees were treated in a manner similar to the tests on bean and potato foliage. Both sides of leaves were sprayed with a fine spray. The pricked leaf experiments were not included. In these experiments the results already obtained from the previous experiments were verified and some additional data secured. It had been the intention to use the more common varieties of fruits. Other circumstances, however, including the demands of other experiments, made this impossible, and only those varieties were utilized that were available at the time. The untreated leaves and fruit of the same tree were used as checks. The peach trees used had all been set out the spring of 1911.

Lime at the rate of ten pounds to 50 gallons water caused no injury to the foliage, or fruit, of the following trees, comprising all that were tested:

	Variety	Sprayed
Apple		
	Grimes	Leaves (in partial shade)
	Grimes	Leaves (in sun)
	Grimes	Fruit (in shade)
	Red Astrachan	Leaves (in shade)
	Red Astrachan	Fruit (in shade)
	Delicious	Leaves (in sun)
Pear		
	Anjou	Leaves (in partial shade)
	Anjou	Leaves (in sun)
	Anjou	Fruit (in shade)
	Kieffer	Leaves (in sun)
	Kieffer	Leaves (in partial shade)
Cherry		
	Seedling	Leaves (in partial shade)
Peach		
	Triumph	Leaves (in sun)
	Crosby	Leaves (in sun)
Plum		
	Miracle	Leaves* (in sun)

*It is interesting to note that, seven weeks after the application, these leaves (16) were green and healthy. The unsprayed laves were for the most part diseased and full of "shot holes."

Ground sulfur, used at the rate of ten pounds to 50 gallons of water, was not injurious to any of the varieties treated. The following varieties were used: (After drying much of the sulfur was blown off by the wind).

Variety	Sprayed
Apple	
Delicious	Leaves (in sun)
Autumn Sweet	Leaves (in shade)
Autumn Sweet	Fruit (in shade)
Pear	
Madeline	Leaves (in sun)
Madeline	Fruit (in sun)
White Doyenne	Leaves (in partial shade)
White Doyenne	Fruit (in sun)
Cherry	
Seedling	Leaves (in sun)
Windsor	Leaves (in shade)
Peach	
Globe	Leaves (in sun)
Globe	Leaves (in shade)
Greenboro	Leaves (in partial shade)
Plum	
Red Egg	Leaves (in sun)
Chalco	Leaves (in sun)

For testing calcium sulfite, ordinary plaster paris was used at the rate of ten pounds to 50 gallons water. In no case was injury caused. The following were the varieties treated:

Variety	Sprayed
Apple	
Longfellow	Leaves (in partial shade)
Longfellow	Fruit (in shade)
Stark	Leaves (in sun)
Stark	Fruit (in shade)
Pear	
Louise	Leaves (in partial shade)
Louise	Fruit (in shade)
Bartlett	Leaves (in shade)
Bartlett	Fruit (in shade)
Peach	
Late Crawford	Leaves (in partial shade)
Lemon Cling	Leaves (in sun)
Cherry	
Early Purple	Leaves (in partial shade)
Knight	Leaves (in partial shade)
Plum	
Quackenboss	Leaves (in partial shade)
Bradshaw	Leaves (in partial shade)
Bradshaw	Fruit (in shade)

Gipsum was used at the rate of ten pounds to 50 gallons for ascertaining whether calcium sulfate could be injurious on foliage or fruit. No cases of injury occurred. The varieties sprayed were:

Variety	Sprayed
Apple	
Longfellow	Leaves (in shade)

	Longfellow	Fruit (in shade)
	Stark	Leaves (in sun)
	Stark	Fruit (in shade)
Pear		
	Louise	Leaves (in shade)
	Louise	Fruit (in shade)
	Bartlett	Leaves (in partial shade)
	Bartlett	Fruit (in shade)
Peach		
	Late Crawford	Leaves (in sun)
	Lemon Cling	Leaves (in shade)
Cherry		
	Early Purple	Leaves (in shade)
	Knight	Leaves (in shade)
Plum		
	Quakenboss	Leaves (in partial shade)
	Bradshaw	Leaves (in partial shade)
	Bradshaw	Fruit (in shade)

Calcium thiosulfate was used in a 1% and a 3% solution. Of all the varieties treated with the 1% solution only one, a seedling cherry, was injured. In this case the smallest and largest leaves were scorched; the middle-sized leaves remained uninjured. The following varieties were not injured by the spray·

	Variety	Sprayed
Apple		
	Roxbury	Leaves (in partial shade)
	Roxbury	Fruit (in shade)
	Stark	Leaves (in partial shade)
	Stark	Fruit (in shade)
	Longfellow	Leaves (in shade)
	Longfellow	Fruit (in shade)
Pear		
	Clapp Favorite	Leaves (in shade)
	Clapp Favorite	Fruit (in shade)
	Gifford	Leaves (in sun)
	Gifford	Fruit (in sun)
Peach		
	Wonderful	Leaves (in partial shade)
	Champion	Leaves (in partial shade)
Cherry		
	Gov. Wood	Leaves (in shade)
Plum		
	Quackenboss	Leaves (in shade)
	Green Gage	Leaves (in shade)

In this series, the direct rays of the sun did not cause the solution to become injurious. In the one case of injury mentioned above, the leaves were all in a shaded portion of the tree.

A 3% solution of calcium thiosulfate proved more injurious on pear and cherry than on any of the other trees sprayed. Unfortunately, standard varieties of the fruit trees were not available. This series of experiments, however, is primarily to obtain data on the injurious ingredients of lime-sulfur. Any data on varietal susceptibility is incidental, though none the less valuable. Plum and peach leaves in the sun or shade were not injured. Of the apple, only the leaves of the

Longfellow, a variety that does not occur in this country commercially, were injured. The results obtained follow:

	Variety	Sprayed	Remarks
Apple			
	Roxbury	Leaves (in partial shade)	No injury
	Roxbury	Fruit (in shade)	No injury
	Stark	Leaves (in shade)	No injury
	Stark	Fruit (in shade)	No injury
	Longfellow	Leaves (in shade)	Slight scorch areas on all leaves
	Longfellow	Fruit (in shade)	No injury
Pear			
	Clapp Favorite	Leaves (in shade)	Tips of almost all leaves scorched
	Clapp Favorite	Fruit (in shade)	No injury
	Gifford	Leaves (in sun)	2 leaves discolored
	Gifford	Fruit (in sun)	Several 'scorch specks'
Peach (set in the spring of the year)			
	Wonderful	Leaves (in partial (shade)	No injury
	Champion	Leaves (in sun)	No injury
Cherry			
	Seedling	Leaves (in shade)	Tips and edges scorched
	Gov. Wood	Leaves (in shade)	All leaves scorched along the edges
Plum			
	Quackenboss	Leaves (in partial shade)	No injury
	Green Gage	Leaves (in partial shade)	No injury

Both the calcium thiosulfate and the calcium polysulfides were used immediately after being prepared, to avoid too much decomposition. A 1% calcium polysulfide which would only approximately represent the polysulfides present in a one to 35 dilution, caused no injury whatever. The following varieties were used:

	Variety	Sprayed
Apple		
	Northern Spy	Leaves (in sun)
	Northern Spy	Fruit (in shade)
	Van Wick Sweet	Leaves (in partial shade)
	Van Wick Sweet	Fruit (in shade)
Pear		
	Mt. Vernon	Leaves (in sun)
	Mt. Vernon	Fruit (in shade)
	Patrick Barry	Leaves (in partial shade)
	Patrick Barry	Fruit (in shade)
Peach		
	Crosby	Leaves (in sun)
	Elberta	Leaves (in sun)
Cherry		
	Coe	Leaves (in partial shade)
	Lincoln	Leaves (in partial shade)
Plum		
	Quackenboss	Leaves (in shade)

Bradshaw	Leaves (in partial shade)
Bradshaw	Fruit (in shade)

A 3% solution of calcium polysulfides caused most injury to pear and cherry. No injury was caused on the leaves of young peach. Slight injury was caused on apple. The injury was more severe on plum foliage.

The results obtained follow:

Variety	Sprayed	Remarks
Apple		
Keswick Codlin	Leaves (in sun)	Several leaves discolored
Keswick Codlin	Fruit (in sun)	No injury
King	Leaves (in partial shade)	No injury
King	Fruit (in shade)	Scorch specks
Pear		
Clapp Favorite	Leaves (in partial shade)	Scorch specks on several leaves
Clapp Favorite	Fruit (in shade)	Few scorch specks
Bartlett	Leaves (in shade)	Edges of several leaves scorched
Bartlett	Fruit (in shade)	Scorch specks prominent
Peach		
Ark. Beauty	Leaves (in sun)	No injury
Cherry		
Seedling	Leaves (in partial shade)	All leaves scorched along edges
Major Francis	Leaves (in shade)	All leaves scorched along edges
Plum		
Quakenboss	Leaves (in shade)	Edges of all leaves scorched
Green Gage	Leaves (in shade)	No injury
Green Gage	Fruit (in shade)	Scorched areas on skin
Abundance	Leaves (in partial shade)	Several leaves scorched

The 5% solution of calcium polysulfides, a dilution much stronger than is found in a summer strength of lime-sulfur, did not cause any injury to the foliage of the young peach trees. It will be recalled that these were young trees set out in the spring of the year. No experiments were conducted on foliage of bearing peach trees. None of the cases of injury would be considered very severe. The injury to apple foliage was slight. The injury to pear foliage was more severe than to the foliage of any other fruit trees. The injury on the pear fruit which we call "scorch specks" is quite characteristic. (See illustrations.) The results obtained follow:

Variety	Sprayed	Remarks
Apple		
Roxbury	Leaves (in shade)	No injury
Roxbury	Fruit (in shade)	No injury
Stark	Leaves (in shade)	Scorch areas on leaves
Pear		
Bartlett	Leaves (in parital shade)	Scorch areas on most leaves
Bartlett	Fruit (in shade)	Scorch specks
Souvenir	Leaves (in sun)	Scorch areas on leaves

	Souvenir	Fruit (in sun)	Scorch specks
Peach			
	Triumph	Leaves (in sun)	No injury
	Globe	Leaves (in sun)	No injury
Cherry			
	Early Purple	Leaves (in parital shade)	Scorch spots on all leaves
	Napoleon Bigarreau	Leaves (in parital shade)	No injury
Plum			
	Green Gage	Leaves (in sun)	No injury
	Green Gage	Fruit (in shade)	Scorch specks
	Bradshaw	Leaves (in shade)	Scorch spots on leaves
	Bradshaw	Fruit (in shade)	No injury

This series of experiments was concluded with tests of different strengths of commercial lime-sulfur upon fruit and foliage. For this purpose a clear concentrate testing 37° B. was diluted to the strength required. In recording, all dilutions were reduced to their equivalents in a similar concentrate testing 30° B. This was merely for convenience; and we have assumed a 30° B. concentrate that is identical chemically with the 37° B. used—a condition, however, that is rather rare. (This will be discussed later). A dilution, then, recorded as 1 to 10 means at 30° B., and the dilution actually used was 1 to 12⅓ of a 37° B. concentrate. Similar procedure was followed for the other dilutions.

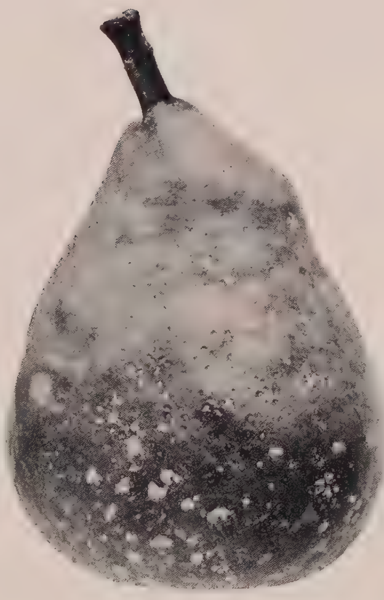
A 1 to 30 lime-sulfur dilution (at 30° B.) slightly injured foliage of pear and Sweet Bough apple. The fruit of pear and plum was specked by this strength. No further injury occurred. The results follow:

	Variety	Sprayed	Remarks
Apple			
	Sweet Bough	Leaves (in shade)	Slight scorch on several leaves
	Sweet Bough	Fruit (in sun)	No injury
	Oldenburg	Leaves (in partial shade)	No injury
	Oldenburg	Fruit (in shade)	No injury
Pear			
	Knight Seedling	Leaves (in partial shade)	Scorch spots on several leaves
	Clapp Favorite	Leaves (in partial shade)	Scorch at edges and tips of leaves
	Clapp Favorite	Fruit (in shade)	Scorch specks
Peach			
	Late Crawford	Leaves (in sun)	No injury
	Lemon Cling	Leaves (in sun)	No injury
Cherry			
	Seedling	Leaves (in sun)	No injury
	Knight Early	Leaves (in shade)	No injury
Plum			
	Tennant	Leaves (in sun)	No injury
	Green Gage	Leaves (in sun)	No injury
	Green Gage	Fruit (in shade)	Scorch specks

A dilution of 1 to 25 (at 30° B.) was slightly more injurious than the 1 to 30 dilution. No injury occurred to apple or to young peach trees. Both leaves and fruit of pear were injured. Injury to cherry and plum was slight. The results follow:

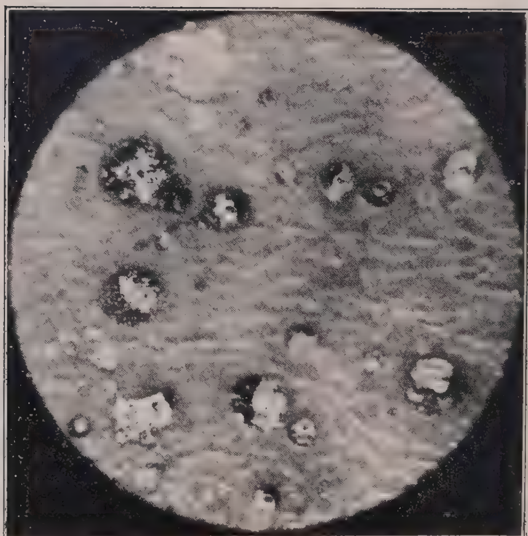
Plate I(a).

''Scorch specks'' on pear (Clapp Favorite) caused by lime-sulfur 1-30 (at 30° B.)



''Scorch specks'' on Souvenir pear caused by a 5% solution of calcium polysulfide. (The dried spray shows white.)

Plate I(b).

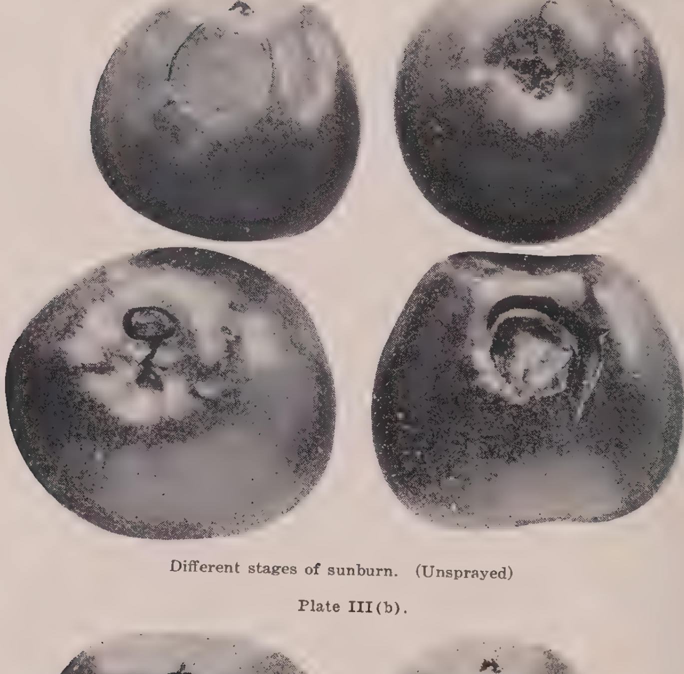


"Scorch specks" enlarged. (Dried spray shows white.)

Plate II.

Type of injury encountered in the Hood River Experiments. Slightly enlarged. (Apples had been taken from the tree six days before being photographed.)

Plate III(a)



Different stages of sunburn. (Unsprayed)

Plate III(b).

Sunburn. (One apple unsprayed, others sprayed 1:30, 1:35, and 1:50 respectively.)

Variety	Sprayed	Remarks
Apple		
Melon	Leaves (in partial shade)	No injury
Melon	Fruit (in shade)	No injury
Crab		
Martha	Leaves (in shade)	No injury
Martha	Fruit (in shade)	No injury
Pear		
Louise	Leaves (in partial shade)	Scorch spots on all leaves
Louise	Fruit (in shade)	Scorch specks
Bordeaux	Leaves (in shade)	Scorch spots prominent
Bordeaux	Fruit (in shade)	Scorch specks
Peach		
Late Crawford	Leaves (in shade)	No injury
Lemon Cling	Leaves (in sun)	No injury
Cherry		
Coe	Leaves (in partial shade)	Leaves discolored
Seedling	Leaves (in sun)	No injury
Plum		
Sugar	Leaves (in sun)	No injury
Imperial	Leaves (in sun)	No injury
Bradshaw	Leaves (in partial shade)	Tips scorched
Bradshaw	Fruit (in shade)	No injury

A 1 to 20 dilution of lime-sulfur (at 30° B.) caused still more injury. The injury to apple foliage was very slight; but the peach trees were defoliated by the spray. The results follow:

Variety	Sprayed	Remarks
Apple		
Wolf River	Leaves (in partial shade)	Slight discoloration
Wolf River	Fruit (in sun)	No injury
Shiawassee	Leaves (in sun)	No injury
Shiawassee	Fruit (in sun)	No injury
Pear		
Flemish Beauty	Leaves (in sun)	Scorch on all leaves
Flemish Beauty	Fruit (in shade)	Scorch specks
Idaho	Leaves (in partial shade)	Scorch on edge and tip of several leaves
Idaho	Fruit (in shade)	Scorch specks
Peach		
Wonderful	Leaves (in sun)	Defoliation
Early Columbia	Leaves (in sun)	Defoliation
Cherry		
Willamette	Leaves (in shade)	Slight discoloration of young leaves
Rockport	Leaves (in sun)	Scorch on edges and tips
Plum		
Reine-Claude de Bavay	Leaves (in shade)	No injury
Quakenboss	Leaves (in shade)	Scorch on edges and tips

A 1 to 15 dilution (at 30° B.) injured the foliage but not the fruit of the apple. All other tests resulted in injury. This strength is great-

er than a summer strength and would not ordinarily be used for summer spraying. The results follow:

	Variety	Sprayed		Remarks
Apple				
	Keswick Codlin	Leaves	(in partial shade)	All leaves discolored
	Keswick Codlin	Fruit	(in shade)	No injury
Pear				
	Vicar	Leaves	(in sun)	Scorched
	Vicar	Fruit	(in shade)	Scorch specks
	Comet	Leaves	(in partial shade)	Scorch spots
	Comet	Fruit	(in sun)	Scorch specks
Peach				
	Early Columbia	Leaves	(in sun)	Defoliation
	Wonderful	Leaves	(in sun)	Defoliation
Cherry				
	Lincoln	Leaves	(in shade)	Scorch and discolora-(toin
	Lewelling	Leaves	(in shade)	Scorch and discolora-(toin
Plum				
	Imperial	Leaves	(in partial shade)	Scorch areas
	Bradshaw	Leaves	(in partial shade)	Discoloration and (scorch
	Bradshaw	Fruit	(in shade)	Slight scorch

The strongest solution used was a 1 to 10 dilution (at 30° B.) This is a winter strength and would in no case be used upon fruit or foliage. Even at this strength apple foliage was but slightly injured and the fruit not at all injured. All other tests resulted in injury. The results follow:

	Variety	Sprayed		Remarks
Apple				
	Van Wick Sweet	Leaves	(in shade)	Scorch spots prominent
	Van Wick Sweet	Fruit	(in sun)	No injury
	Ewalt	Leaves	(in shade)	No injury
	Ewalt	Fruit	(in shade)	No injury
Pear				
	Knight Seedling	Leaves	(in partial shade)	Scorch spots prominent
	Knight Seedling	Fruit	(in shade)	Scorch spots
	Clairgeau	Leaves	(in partial shade)	Scorch spots prominent
	Clairgeau	Fruit	(in shade)	Scorch specks
Peach				
	Foster	Leaves	(in sun)	Defoliation
	Champion	Leaves	(in partial shade)	Defoliation
Plum				
	Bradshaw	Leaves	(in partial shade)	Scorch spots prominent
	Green Gage	Leaves	(in partial shade)	Scorch severe
	Green Gage	Fruit	(in shade)	Scorch specks

These sprays were applied during the period from August 3 to August 15. All but four days of this month were clear. Of the four

days, three were partly cloudy and on August 18, .02 inches precipitation fell. During September precipitation occurred on the first five days and frequently thereafter.

The mean temperature during August was 67.5°, the maximum reaching 92°. The mean temperature during September was 54°, the maximum reaching 87°.

On the whole, our weather records revealed no conclusive effect upon the action of the sprays. There was practically no rain during two or three weeks after the applications. The direct rays of the sun did not seem to cause any apparent increase in injury. In this connection it should be recalled that the maximum did not go above 92° and that the experiments were conducted at Corvallis, where the soil contained sufficient moisture for the trees.

As has been stated, the data on varietal susceptibility to lime-sulfur injury were incidental, the variation in occurrence of injury being well explained by varietal resistance. The main point in this series of experiments has been proved:

Lime-sulfur injury, in the proper use of the term, is caused by the calcium polysulfides, and to a less extent may be caused by calcium thiosulfate. All other normal ingredients occurring in the lime-sulfur spray, either before or after its application, are harmless.

REMARKS ON SOME FACTORS AFFECTING LIME-SULFUR INJURY.

In these remarks it is not intended to discuss the various causes of injury to fruit and foliage, but rather to mention some of the factors that may influence the occurrence of injury due directly to the lime-sulfur. Among these factors may be found some of the bases for the anomalous results encountered.

The main factor in the occurrence of lime-sulfur injury is the presence of soluble sulfides. There is no offhand method of determining the amount of soluble sulfides in the concentrated mixture. Determining the specific gravity is a crude and very inexact basis of ascertaining the "strength" of the spray. **A dozen samples of lime-sulfur all having the same specific gravity may show no two samples alike in per cent of soluble sulfides. Furthermore, a sample having a low specific gravity may have a greater per cent of soluble sulfides than a sample having a higher specific gravity.**

This is easily explained. The specific gravity is determined not only by the sulfides in solution but also by the calcium thiosulfate in solution. Hence a specific gravity reading of a lime sulfur preparation is really a reading of several solutions, and it is impossible to tell the amount of each material in solution by only knowing the density of the resulting preparation. The question then arises what use is the sole knowledge of the density of lime-sulfur spray. Specific gravity readings have been so widely accepted without question as explaining the comparative nature of the mixture that we hesitate to answer, "No use whatever." In the lack of a more exact, practical method, a specific gravity reading is of use to the fruitgrower in conveying a general idea of the dilution of the concentrate. For purposes of accuracy the specific gravity reading alone is inadequate.

It is evident, then, that one should not expect a lime-sulfur spray of a certain density to cause injury solely because a spray of a lower density caused injury, for the lower testing spray may have more sulfides in solution. The other sample would, of course, compensate by having more calcium thiosulfate in solution; which, however, would not result in a preparation having the same injurious or non-injurious properties. This, then, accounts for that class of apparent anomalies

in which a lighter testing spray has caused injury and a heavier testing spray has caused none. **The density of a lime-sulfur spray does not indicate its power of causing leaf or fruit injury.** The property of causing injury is located, for the most part, in the soluble sulfides, and as has been stated the specific gravity does not indicate to what extent these sulfides are present. A color test, though not practical for the fruit grower, would be more accurate.

Though the amount of soluble sulfides in the spray may be known, other factors still remain to modify, sometimes radically, the power of a spray to produce injury to foliage or fruit. This modification is almost always downward; that is, modification in almost every case implies the destruction of the soluble sulfides as such.

Beginning with the boiled concentrate, every operation performed before the spray comes in contact with the tree is accompanied by more or less modification. The dilution of the concentrate gives an impetus to the chemical decomposition; the breaking up of the stream into a spray causes further decomposition—the finer the spray, the greater the decomposition; contact with the oxygen and carbon dioxide in the air causes the sulfides and the thiosulfate to break down.

The knowledge, then, of the analysis of the concentrate does not indicate the analysis of the drop that finally rests on the leaf, and it is due to the sulfur in solution in this drop that the injury occurs. When a spray of lime-sulfur dries leaving a white residue, it is good evidence that the soluble sulfides have for the most part been broken down. On the other hand, a yellow or orange colored residue denotes the existence of calcium polysulfides—the most injurious ingredient.

The explanations we have offered above do not account for the cases that have been reported wherein applications from the same tank or barrel have caused injury in one instance and not in another. This may also be explained, perhaps, by considering the exact conditions encountered.

In a barrel or tank of lime-sulfur concentrate sediment is almost always present. This may amount to over 30% (by volume) in homemade preparations. Let us suppose a barrel of the concentrate contains 10% sediment by volume; that is, in the fifty gallon barrel five gallons of sediment are present. The liquid tests 30° B. and sixteen gallons are drawn from the top of the barrel into a 150 gallon sprayer which is then filled with water. The second sixteen gallons made up to 150 gallons will result in an approximately equivalent spray. The third sixteen gallons, however, though still testing 30° are in reality diluted by the sediment present so that a weaker concentrate is being used. Let us suppose that in the last sixteen gallons, three gallons of sediment are present. Then in diluting these sixteen gallons to 150 gallons, instead of having a dilution of about 1 to 9½, the dilution is about 1 to 11½ because only thirteen gallons of the concentrate are liquid. For summer use the dilutions would be greater and the difference in dilution betwen the top and bottom of the barrels would be correspondingly increased. In the above case, granting that the dilution for summer use would be three times that for winter use, the actual dilution of the first sixteen gallons would be about 1 to 28½ while that of the last sixteen gallons (of which only thirteen are liquid) would be about 1 to 35.

With this possibility it is seen that the same barrel may give in one case an injurious strength and in another a non-injurious strength, though the concentrate tests the same in both instances and the dilutions are apparently the same in both cases. Almost all users of lime-sulfur have noticed that the concentrate frequently becomes darker as it is drawn from near the bottom of the barrel. The dark color is due

to the presence of sediment. In one of our last experiments we used a commercial preparation testing 36° B. As we neared the bottom of the solution the color darkened until we were drawing off a dark green, almost black, concentrate, indicating a large amount of sediment present. In accordance with this explanation, the first applications would be the injurious ones if the concentrate were drawn from the top of the barrel. On the other hand, if the concentrate were drawn from the bottom of the barrel, the last application would be injurious. If the concentrate were agitated before drawing off for dilution, a more even series of dilutions would result. This, however, is practically never done.

Other factors, that figure in the production of spray injury are well known; such as varietal resistence, individual variation, physiologic condition of the part sprayed at the time of the application, presence of some caustic material in the spray, etc. It is not our intention to discuss these items at the present time. The ponit we wish to emphasize is this:

The specific gravity alone of a lime-sulfur spray does not indicate to what extent sulfides are in solution and different experiments using the densities of different concentrates as bases for dilution can not be compared accurately, so far as spray injury is concerned.

PREVENTION OF LIME-SULFUR INJURY.

In discussing the prevention of lime-sulfur injury we again refer only to that injury to fruit or foliage caused by the dissolved sulfur in the spray. A fine mist spray would not be as injurious as a coarse or drenching spray. It is good horticulture, in fact, to apply only a light even coating of spray, where possible. Though this procedure can be followed in many parts of the country, however, it is difficult for some regions. In some of the fruit growing sections of Oregon, a fine mist spray can be rarely used. Frequently the winds are strong enough to necessitate a coarse spray in order that the tree may be sprayed thoroughly. In such cases no choice remains; a coarse spray must necessarily be applied. Drenching, however, may be avoided by using care and judgment.

In cases of limesulfur injury induced by previous fungus infection, there is no question as to the proper procedure. It is much more advisable to destroy the leaves by means of the spray than to allow the fungus to become destructive.

The most simple method that presents itself of avoiding lime-sulfur injury is to weaken the soluble sulfides by increased dilution. From our own experiences and those of several others we are led to believe that lime-sulfur properly made (i. e., boiled for not more than one hour) is not injurious at the strengths generally rcommended. Home-boiled preparations are rarely injurious for this reason. On the other hand, we know of lime-sulfur factories that prolong boiling for three or four hours. This gives a concentrate that is more injurious (on account of the greater proportion of sulfides in solution) than a properly made concentrate testing the same specific gravity. It is rather difficult to recommend a practical method of deciding whether the concentrate is liable to be injurious or uot, and the procedure to follow upon ascertaining this point. In general, a concentrate that has been boiled for not more than one hour, may be considered safe at the dilutions generally recommended (1 to 30, at 30° B. for apples, 1 to 40 for pears.) Again we wish to call attention to the fact that we are considering only that injury caused primarily by the sulfides in the spray. Our own experiments have shown, in one case, that injury followed an application of lime-sulfur diluted 1 to 75. This, however,

was not strictly lime-sulfur injury but injury due to other causes to be explained later.

Another method of avoiding lime-sulfur injury is by rendering the sulfides insoluble. This may be done by adding various substances to the spray that will break down, not necessarily all the sulfides in solution, but enough to render the remaining sulfides non-injurious. It may be argued, however, that in breaking down the polysulfides the insecticidal properties of the spray are impaired. In reply it may be noted that lime-sulfur is used during the growing season primarily as a fungicide and its insecticidal value at the strength used upon foliage is questionable.

These studies were carried on solely from the standpoint of injury to fruit or foliage, and the results should not be taken for more than we represent them. If we find that various forms of modified lime-sulfur are suitable from the standpoint of preventing lime-sulfur injury, we do not wish it inferred that we recommend this material in preference to the unmodified lime-sulfur spray. Before determining this question, and after deciding that the modified lime-sulfur is non-injurious and practical, the following are some of the problems that must be investigated: The exact nature of the reaction between the lime-sulfur and the material used to modify the spray; the chemical changes that may take place upon exposure to air after the spray has been applied; the fungicidal properties of the spray (both in the field and the laboratory). Only by such procedure can we hope to lay the bases of logical spraying. The past history (even to the present time) of lime-sulfur spraying is to quite an extent a history of errors and acceptance upon faith.

The objective feature in the modification of limesulfur is the precipitation of the calcium polysulfides into sulfur or insoluble sulfides. The mere fact of the sulfur being in an insoluble form is not sufficient cause for considering the fungicidal properties impaired; for the fungicidal element in the lime-sulfur spray is sulfur itself; and upon the tree it is in the form, for the most part, of free sulfur, insoluble and in finely divided form. It is quite natural, then, to suppose that finely divided sulfur in any combination would be fungicidal. The extent of this property would have to be worked out in the laboratory and in the field.

Tests were conducted in August, 1911, with various preparations of modified lime-sulfur upon foliage and fruit. In these experiments the following materials were used to break down some of the polysulfides: Iron sulfate, copper sulfate, zinc sulfate, sulfuric acid, and carbon dioxide.

A clear concentrate was diluted 1 to 20 (at 30° B.)* and modified by the addition of iron sulfate at the rate of four pounds of iron sulfate to 100 gallons of the diluted spray. The iron sulfate was previously dissolved in water. The resulting precipitate consisted of sulfides of iron, all insoluble. This preparation was injurious only to the leaves of a seedling cherry. These leaves were in the shade and on the same tree that was injured by a 1% calcium thiosulfate solution in the experiments previously reported. A probable explanation of this injury is that enough sulfur remained in the solution to injure this particular seedling which had previously proved to be very susceptible to lime-sulfur injury. However, a sufficient amount of the polysulfides was

*We still adhere, unwillingly to this crude method of designating the "strength" of the concentrate, as we have no better method short of a chemical analysis. The concentrate used tested 37° B. A chemical analysis was not made.

broken down to render all the remaining tests non-injurious. The following trees were sprayed:

Variety	Sprayed
Apple	
Shiawassee	Leaves (in partial shade)
Shiawassee	Fruit (in shade)
Maiden Blush	Leaves (in partial shade)
Maiden Blush	Fruit (in shade)
Pear	
Clairgeau	Leaves (in partial shade)
Clairgeau	Fruit (in shade)
Unnamed	Leaves (in shade)
Unnamed	Fruit (in shade)
Peach (set in the spring of the year)	
Foster	Leaves (in partial shade)
Greenboro	Leaves (in partial shade)
Cherry	
Unnamed	Leaves (in shade)
Plum	
Quackenboss	Leaves (in shade)
Bradshaw	Leaves (in partial shade)

Lime-sulfur modified with iron sulfate has been used successfully as a fungicide by Volck in California and by Waite*. Wallace, in laboratory experiments, found that the addition of iron sulfate to lime-sulfur solution "seemed to have but very little effect on the effciency of the latter if any, perhaps slightly increasing it."

To a lime-sulfur solution of 1 to 20 (at 30° B.) was added copper sulfate at the rate of four pounds to 100 gallons of the diluted spray. The copper sulfate was dissolved before adding to the lime-sulfur. The resulting precipitate consisted of sulfides of copper. No injury whatever was caused by this spray. The following varieties were sprayed:

Variety	Sprayed
Apple	
Maiden Blush	Fruit (in shade)
Maiden Blush	Leaves (in partial shade)
Shiawassee	Fruit (in shade)
Shiawassee	Leaves (in shade)
Pear	
Unnamed	Fruit (in shade)
Unnamed	Leaves (in shade)
Clairgeau	Fruit (in partial shade)
Clairgeau	Leaves (in partial shade)
Peach	
Greenboro	Leaves (in partial shade)
Foster	Leaves (in sun)
Cherry	
Unnamed	Leaves (in partial shade)
Seedling	Leaves (in partial shade)
Plum	
Quackenboss	Leaves (in partial shade)
Bradshaw	Leaves (in partial shade)

The use of zinc sulfate in modifying lime-sulfur was not as satisfactory as copper or iron sulfate. To a 1 to 20 dilution of lime-sulfur was added zinc sulfate at the rate of four pounds to 100 gallons. Some foliage injury was caused. No experiments were carried on to ascertain

*And by several others since the above writing.

whether this injury would have been avoided by using more zinc sulfate. The results obtained follow:

	Variety	Sprayed	Remarks
Apple			
	Pewaukee	Leaves (in shade)	No injury
	Pewaukee	Fruit (in shade)	No injury
	Western Beauty	Leaves (in shade)	No injury
	Western Beauty	Fruit (in shade)	No injury
Pear			
	White Doyenne	Leaves (in shade)	Edges of several leaves scorched
	White Doyenne	Fruit (in shade)	No injury
	Cole Seedling	Leaves (in partial shade)	No injury
	Cole Seedling	Fruit (in sun)	No injury
Peach			
	Perfection	Leaves (in partial shade)	No injury
	Yellow Rare-ripe	Leaves (in partial shade)	No injury
Cherry			
	Windsor	Leaves (in partial shade)	No injury
	Gov. Wood	Leaves (in partial shade)	Several leaves scorched
Quince		Leaves (in sun)	
	Champion	Leaves (in partial shade)	No injury
	Pineapple		Slight scorch

Another form of modified lime-sulfur was made by adding a low-grade commercial sulfuric acid to a dilution of 1 to 15. The strength of the acid or amount used was not recorded and the experiment at best can be considered only indicative. The acid was added until the polysulfides remaining gave the spray an amber color. The reaction was violent, much hydrogen sulfide being liberated. The precipitate was sulfur in a very finely divided form. The original dilution of the lime-sulfur was at the rate of 1 to 15. Apparently enough polysulfides remained unmodified to cause some injury. Undoubtedly, however, this injury could have been avoided by the addition of more acid, or the use of a greater dilution of lime sulfur. The results obtained follow:

	Variety	Sprayed	Remarks
Apple			
	Soulard (crab)	Leaves (in partial shade)	No injury
	Soulard (crab)	Fruit (in sun)	No injury
	Northern Spy	Leaves (in shade)	Slight discolorations
	Northern Spy	Fruit (in sun)	No injury
Pear			
	Vicar	Leaves (in partial shade)	No injury
	Vicar	Fruit (in shade)	No injury
	Louise	Leaves (in partial shade)	No injury
	Louise	Fruit (in partial shade)	No injury
Peach			
	Elberta	Leaves (in partial shade)	No injury

	Early Crawford	Leaves (in partial shade)	No injury
Cherry			
	Lawrence	Leaves (in partial shade)	Several leaves scorched
	Seedling	Leaves (in shade)	Leaves scorched
Plum			
	Bradshaw	Leaves (in shade)	No injury
		Leaves (in sun)	No injury

Carbon dioxide was run into a 1 to 15 dilution of lime-sulfur until the remaining polysulfides gave the solution a clear amber color. The amount of gas used was not measured and this experiment is likewise qualitative rather than quantitive. The sulfur was precipitated into a finely divided form of free sulfur. No injury whatever was caused. The following varieties were used:

	Variety	Sprayed
Apple		
	Soulard (crab)	Leaves (in shade)
	Soulard (crab)	Fruit (in shade)
	Northern Spy	Leaves (in shade)
	Northern Spy	Fruit (in shade)
Pear		
	Vicar	Leaves (in shade)
	Vicar	Fruit (in shade)
	Louise	Leaves (in shade)
	Louise	Fruit (in shade)
Peach		
	Elberta	Leaves (in partial shade)
	Early Crawford	Leaves (in partial shade)
Cherry		
	Seedling	Leaves (in partial shade)
	Lawrence	Leaves (in shade)
Plum		
	Quackenboss	Leaves (in partial shade)
	Bradshaw	Leaves (in partial shade)

The advantage in properly using a gas sprayer where lime-sulfur injury is liable to occur is evident. The gas coming in contact with the spray breaks down the polysulfides thereby reducing the chances of causing injury. Wallace, in laboratory experiments, concluded that "the precipitation by the gas did not materially increase or decrease the fungicidal value."

REMARKS ON THE SELF-BOILED LIME-SULFUR.

The boiled lime-sulfur spray is very injurious to peach foliage even when much diluted. To avoid this injury the self-boiled lime-sulfur has been adopted almost universally. This has been the result, to a great extent, of the experiments of Scott and Waite, of the Bureau of Plant Industry. The self-boiled lime-sulfur, though admitted to be not as good a fungicide as the boiled wash, has been found satisfactory as a fungicide for peach trees in foliage.

The primary reason for its use is the fact that foliage injury is reduced or eliminated. This is because very little of the soluble sulfides is present. In other words, the spray is primarily a mixture of lime and sulfur rather than a combination. Scott says, "The finely divided sulfur in mechanical mixture with the lime is depended upon

for the fungicidal action rather than the sulfides in solution."

If this be so, then the idea in using the self-boiled preparation is not that any new compounds are formed, but that the sulfur is in the form of free sulfur rather than soluble sulfides. Why, then, is this material boiled at all? What is the necessity of the lime since very little of the sulfur goes into combination and the function of lime in lime-sulfur is to hold the sulfur in solution? We are led to believe that the self-boiled lime-sulfur is unneccessary as such. If the sulfur is wanted, why not spray sulfur suspended in water? Soap, at the rate of two pounds to 50 gallons of spray, could be added to increase the power of suspension. Or, if sulfur were required in a more finely divided form, why not use the boiled preparation, precipitated by one of the various methods? Or, if the addition of a slight amount of sulfides in solution were required, a weak boiled preparation could be used. Any one of these methods appears more logical than the self-boiled mixture. The various modified lime-sulfurs are fungicidal, non-injurious, practical, and cheap. We confine our ideas to mere remarks at present, leaving the actual field experiments to some future time. The undissolved lime in the self-boiled mixture is useless and materially aids in clogging the nozzle and other parts of the spray machinery, and is the main cause of the objectionable sediment deposited upon the fruit.

THE RELATION OF SUNBURN TO LIME-SULFUR INJURY.

We have several times suggested the presence of other causes for much of the so-called lime-sulfur injury reported. It is our intention in the present article to discuss but one of these causes, perhaps the most common one of all in some parts of the country. Our own experiments gave all the evidences of a typical occurrence of this injury wherein some of the apparently puzzling phenomena observed elsewhere were encountered.

A block of fourteen-year old Newtown apple trees was chosen for the experiment. The orchard was situated in the Hood River Valley on a level stretch of medium soil of volcanic ash. The block consisted of 160 trees in four rows. The 1st, 10th, 20th, 30th, and 40th tree in each row was used as a check. This divided the block into four plots, each plot separated from the next by a cross row of four trees used as checks. This arrangement allowed thirty-two trees in the first plot, thirty-six trees in each of the other three plots and twenty check trees.

Plot I was sprayed with a dilution of 1 to 30 (at 30° B.)* Plot II received a dilution of 1 to 35. Plot III received 1 to 50 and plot IV received 1 to 75. The check trees received no treatment whatever till late in the summer when all the trees received a spray of lead arsenate alone, two pounds to fifty gallons of water, for the second brood of codling moth.

The first application was made April 20 and 21, 1911. The outfit used was a steam engine with a tank holding 103 gallons. A good pressure was maintained and a medium spray was deposited on the trees. At this time the leaf buds were open and the pink of the flower buds was beginning to show.

The second application was made May 15 and 16. In this and the next application a neutral arsenate of lead was used at the rate of two pounds to 50 gallons of diluted spray.

The third application was made on May 31 and June 1. Plots III and IV were sprayed May 31 with practically no breeze stirring. On

*The commercial concentrate tested 35° B.

this day the maximum temperature of Hood River recorded by the observer was 87°. The maximum was probably several degrees higher in the orchard itself. A week before this, on May 24, there had been .45 inches precipitation. Previous to this, on May 17, there had been .70 inches precipitation. In other words, the soil, being well drained naturally and the evaporation from the surface being rapid, was very dry at the time of spraying. Until June 23 there was no rain. On that day .05 inches fell. We mention these itmes on account of the bearing they have on the problem.

Plots I and II were sprayed on June 1, when a strong west breeze was blowing. On this day the maximum recorded by the observer was but 74°. Since May 24 every day had been clear with generally a brisk wind blowing. On June 10, 11 and 12, the maximum recorded by the observed was 91°, 87° and 82° respectively, and the temperature, as stated before, was probably several degrees higher in the orchard sprayed. At this time the young apples were but about four weeks old.

The following note is taken from the writer's record made at the time: "Some three weeks later the men thinnnig the apples noticed that there was some injury. Upon examination the following conditions were found to exist:

"On some low branches extending almost horizontally on the southwest corner of the tree some spray injury was found. The injured spots gave the appearance of having been scorched or baked, in some cases the scorched surface being cracked (see illustration). **The trees that were not sprayed showed practically no injury. Examination of the sprayed trees showed no injury whatever on the north side of the tree and very little on the east side.** The amount of injury to the various plots can be seen by reference to the tables. **Only the parts of apples that received the sunshine were injured.** In other words, **green apples, or the green parts of partly colored apples were uninjured.** (There was no possibility of confusion between the natural coloration and the injured areas).......If one apple in a cluster was scorched the others in the group generally showed scorch ......Only those trees that were sprayed showed injury and the total amount of injury was very small. There was not enough to be termed serious or to cause the slightest alarm."

To ascertain the amount of injury present, the apples of several trees in each plot were counted. **The resulting per cent is only that of the thinned apples and not of the whole crop.**

Table III.

TABLE SHOWING PER CENT OF SCORCH ON THINNED APPLES.

Plot	No. ap ples counted	No. apples scorched	% scorch
I. (1-30)	1946	33	1.93
II. (1-35)	3932	104	2.64
III. (1-50)	1018	5	0.49
IV. (1-75)	1171	2	0.17
Check	5602	3	0.05

In view of the fact that the injured apples were picked in thinning, the actual per cent of scorch would be much lower for the whole crop. The injury was not general in all the trees of one plot but merely occasional in the localities recorded above.

The following items would point to lime-sulfur as the main cause of injury:

1. Injury occurred upon the trees that had previously been sprayed with lime-sulfur.

2. Practically no injury occurred upon trees that remained unsprayed.

3. The plots receiving the weaker spray showed much lower per cent injury than the plots receiving the stronger sprays.

4. In general, the individual injury was more severe where the stronger sprays were used than where the weaker sprays were applied.

The last application, it will be recalled, was a combination spray of lime-sulfur and arsenate of lead. Undoubtedly some cases of injury following such applications are due to the arsenic in the spray. In order to help determine whether the arsenic was responsible for the injury in this case several apples showing severe injury were turned over to the Chemistry Department for analysis. The apples being washed, the flesh directly underneath the injured surface was tested for arsenic. None was found.

It was generally considered by those who observed the injury that it was typical "lime-sulfur injury." At first, therefore, the items mentioned above would lead one to accept lime-sulfur as the sole cause of the injury. However, upon considering all the facts of the case and making a logical analysis, the belief in lime-sulfur as the cause of the injury becomes uncertain.

The following items lead to the belief that if lime-sulfur caused the injury it was not the sole cause, or at least, that there were modifying factors.

1. The injury was by no means general in its distribution throughout the plot; it was almost exclusively restricted to the southwest corner of the tree.

2. The injury was far more common on low-hanging, almost horizontal branches than higher up the tree or upon upright branches.

The restriction of the area of injury to the southwest corner of the tree suggested the sun as a factor in the occurrence of the injury. During the hottest part of the day the sun is in the southwest and the heat given off by the sun to the southwest corner of the tree is much greater than the heat given off to any other part of the tree. The following items tended to strengthen the possibility of the sun being a direct fector in the production of the injury:

1. Injury was found only upon apples exposed to the direct rays of the afternoon sun. Apples shaded by leaves or branches showed no injury.

2. On the individual apple, the injury occurred only upon that part exposed to the direct rays of the afternoon sun. Only the part of the apple that had had sufficient sunlight to begin taking on color was injured, no injury being found upon entirely green apples or upon the green portion of partly colored apples.

In consideration of these items the status of the cause of the injury seemed to be that the lime-sulfur as used was non-injurious under ordinary circumstances but that under the direct rays of the sun during the hottest part of the day the spray upon the trees was rendered injurious. In this assumption however, there are fallacies.

It will be recalled that in our experiments the direct rays of the sun did not noticeably influence the occurrence of lime-sulfur injury. It is true that the temperature at the time of experimentation was not as high as later at Hood River. It is reasonable, however, to expect some indication of the effect of the direct rays of the sun under less extreme conditions. Still, it will be recalled that mere exposure of the spray to the air causes its decomposition, and that decompsoition is synonymous with the removal of the injurious ingredients. Con-

ditions favoring evaporation, such as heat and wind, favor likewise decomposition of the spray. In view of these facts and our previous suggestion that the spray is generally "stronger" when it first touches the tree than at any time later, it is not surprising, then, that the sun should be found without effect in rendering the spray more injurious. According to our statements, in fact, one would expect the spray to be rendered less injurious on account of its more rapid decomposition.

Plot IV received an application of 1 to 75. The calcium polysulfides in this dilution could not have exceeded ⅔ % (at which rate the concentrate would contain about 50% polysulfides, a percentage which is higher than any analysis we have ever seen). After the concentrate had been diluted, agitated, broken up into a spray, thrown into the air and finally placed upon the tree, it is doubtful whether, upon evaporation (which occurred in this experiment in but a few moments) any polysulfides remained. The spray, upon drying, showed no yellow deposit denoting the presence of calcium polysulfides. The residue was white, denoting the decomposition of the polysulfides to calcium sulfite, for the most part.

Hence, if any sulfides remained upon the trees in plot IV—which is doubtful—the amount was very small. The difference between this possible amount and the amount that might be expected in plot I which received an application more than twice as strong would be expected, perhaps, to show some more or less proportional independence of the effect of the direct sun. In other words if the application in plot IV contained enough polysulfides to cause injury in the sunlight (disregarding the possibility of less injury in the sun than in the shade) then the application in plot I could reasonably be expected to cause injury in parts of the tree other than the locations observed.

Wallace and some others think that lime-sulfur injury is caused while the drop is still wet. If this is true, then it is further evidence that the sun's rays would be more likely to decrease rather than increase the injurious properties of the spray. Our own experiments, however, previously recorded, indicate that the injury may occur while the spray is dry.

The above discussion is more or less theoretical and in itself not conclusive. In view of the further evidence recorded, however, the discussion becomes quite significant.

As our course of reasoning advances we find that lime-sulfur as a factor in the cause of the injury, becomes smaller and eventually very doubtful. The following items tend to discard lime-sulfur as a cause of the injury in the Hood River experiments:

1. In our previous experiments it was seen that the leaves were more susceptible to lime-sulfur injury than the fruit. **In the Hood River experiment there was practically no leaf injury.**

2. Lime-sulfur injury on fruit, is in the form of several or many ious sprays. The injuries we encountered in the Hood River experiothers have found this to be the case with arsenical and other injurious sproys. The injuries we encountered in the Hood River experiments were not of this character. A glance at the illustrations will show that the injury upon an apple does not consist of several small scorched spots. **The injury is all in one area.** In the case of slight injury the scorch is most severe at the center and gradually becomes lighter near the edge of the injured area, which is frequently surrounded by a lighter ring.

The location of the injury, both on the tree and on the fruit, indicates a direct relationship between the sun and the injury. The absence of the characters of lime-sulfur injury apparently indicate that the essential cause is not lime-sulfur. How, then, do we explain

the fact that plots I and II showed a greater per cent of injury, and some individual cases much more severe injury than those encountered in plots III and IV; and how do we account for the practical absence of injury on the unsprayed trees?

These phenomena may, perhaps, be accounted for strictly from the physical standpoint. Though the amount of heat absorbed by the fruit does not determine the presence of injury, still, the difference in injury may be accounted for by the difference in the absorption of heat. A green surface does not absorb as much heat as a brown surface. Hence, the part of the apple beginning to color would be more apt to show burn than the uncolored part. When burn does show, the area injured turns brown and thereby gives an impetus to the spread of the injury by the increased absorption of heat. By covering part of the surface with a liquid, radiation of heat from that surface is retarded and more heat stored in the tissues. The spray upon drying leaves a residue. Some of the fruit in plots I and II, on account of the greater concentration of spray used, has a thicker covering of residue than the fruit in plots III and IV—not so thick, however, as to retard heat absorption. The thicker residue retards radiation and increases the absorption of heat to a greater extent than the thin covering and this, in turn, is more conducive to sunburn than no covering, as in the case of the unsprayed fruit.

The residue deposited upon the fruit in one plot is by no means uniform. Hence the amount of variation in amount of injury. In plots I and II, however, a greater per cent of fruit would have sufficient residue to induce sunburn than in plots III and IV. This, perhaps, accounts for the more common occurrence of injury in the first two plots.

The lack of noticeable injury upon the leaves can be explained by the greater transpiration taking place, at the same time promoting radiation of heat. Sun injury is not necessarily an index of the temperature of the surrounding air. The supply of moisture in the soil, the amount of heat radiation from the leaf or fruit, the amount of transpiration together with the amount of radiation from the soil and the sun, must all be taken into consideration.

It is true that the divisions we have outlined between the various plots as causes for the difference in injury are rather fine. But we believe they are justified by the results. By reference to the table previously recorded, it is seen that the unsprayed trees did show a slight injury, somewhat less than one-third of the injury encountered in plot IV, which received a 1 to 75 dilution.

But withal, the state of affairs that we encountered must have been exceptional in order to indicate the evidence we have recorded. Would a little more heat at the time have obliterated these indications? We think so; because for a few days during the middle of July a hot wave caused injury in many parts of the valley. On July 13 and 16 the maximum temperature recorded by the weather bureau observer was 103°. On July 14 and 15 the maximum recorded was 106°. **During these hot days fruit was sunburned equally on sprayed and unsprayed trees.** The character and appearance of the injuries are shown in the illustrations. The sunburned apples photographed were taken from different parts of the valley covering a distance of ten miles.

The sunburn that occurred in the orchard in which the experiments were being carried on was not serious from the standpoint of injuring a large per cent of the crop. Like the previous cases recorded, the injury was confined, to a great extent, to the southwest part of the tree and to fruit exposed to the direct rays of the after-

noon sun. The amount of sunburn found in the various plots follows:

Table IV.

Plot		No. Apples counted	No. Apples sunburned	% sunburn
I.	(1-30)	1243	33	2.65
II.	(1-35)	1094	23	2.10
III.	(1-50)	1452	34	2.34
IV.	(1-75)	1074	19	1.77
Check		2007	25	1.25

It is seen that in general the injury tends to decrease with the weaker spray used, being least on the unsprayed trees. The probable reasons for this tendency we have already discussed.

We understand from those who have been acquainted with conditions, that injury of the character above recorded had been known to occur long before summer spraying came into practice. At that time, however, the desire to produce perfect fruit was not as keen as it is today and the injury was not given much attention.

Later, with the advent of Bordeaux as a summer spray, both sunburn and spray injury occurred, putting many growers in the proper frame of mind to attribute any injury following an application of the spray to the spray itself. It was natural, therefore, to attribute the injury, as recorded above, to the lime-sulfur spray. In fact, without accurate observation and a logical analysis of the results such a conclusion was unavoidable.

The course of reasoning we have outlined above, the course that we have followed, led to the conclusion that **many cases of injury attributed to lime-sulfur are primarily cases of sunburn.** The practice, then, of omitting the summer spray for fear of this character of "spray injury" is not, according to these observations, advisable. As was seen by the effects of the hot wave during July, very little difference could be noticed between the severity of the injury on sprayed or unsprayed fruit.

The heat and related conditions in June were so naturally adjusted that the observations made were possible. Had the conditions been either less or more intense the indications would have been rather difficult to detect. And in this respect, the conditions were exceptional.

We have mentioned the fact that almost annually in some parts of the valley, injury had been reported for some years. Upon looking up the weather records we find temperature conditions which, together with other conditions, might be considered conducive to sunburn. The maximum temperature recorded by the Hood River Obesrver in 1910 was 101°, on July 10 and 19. In 1909, on August 17, the maximum was 101°. In 1908, on the same day of the month, the temperature was 102°, on July 20 it was 101°. The year 1907 saw 102° on June 30 and 103° on July 1. In 1906, the maximum temperature recorded was 106° on July 3. All temperature observations recorded by the Weather Observer indicate the temperature in the shade. The temperature in the sun was, of course, still higher.

Another record exists wherein sunburn occurred upon sprayed and not upon unsprayed fruit. W. H. Volck, in a letter to Mr. F. L. Griffin, dated September 14, 1910, says, "There was also a new development along the physiological line. A spell of hot weather occurred about the last of May and in the orchards freshly sprayed with iron sufide some sunburning of the fruit occurred. There was no sunburning in the unsprayed orchards."

SUMMARY.

1. Lime-sufur injury, in the proper use of the term, is caused by the calcium polysulfides, and to a less extent may be caused by calcium thiosulfate.

2. All other normal ingredients occurring in the lime-sulfur spray, either before or after its application, are harmless to fruit or foliage.

3. Rain following an application of lime-sulfur tends to decrease or prevent injury.

4. The density of a lime-sulfur spray does not indicate its power of causing leaf or fruit injury.

5. Different spray injury experiments using the densities of different concentrates as bases for dilution can not be compared with the accuracy demanded in scientific investigations.

6. Cases reported as lime-sulfur injury are frequently due to other causes, often sunburn.

CONTENTS.

Errata—

On page 4, second paragraph under "Experiments on Potato foliage," the tenth line should follow the fifth line.

On page 5, last paragraph, third line, for CaS_3 read CaS_5.

On page 6, third paragraph, the fourth and fifth sentences should read, "No injury was caused either by the even spray or the drenching spray. To obtain an indication of the possibility of injury from this source, a saturated solution of H_2S was used."